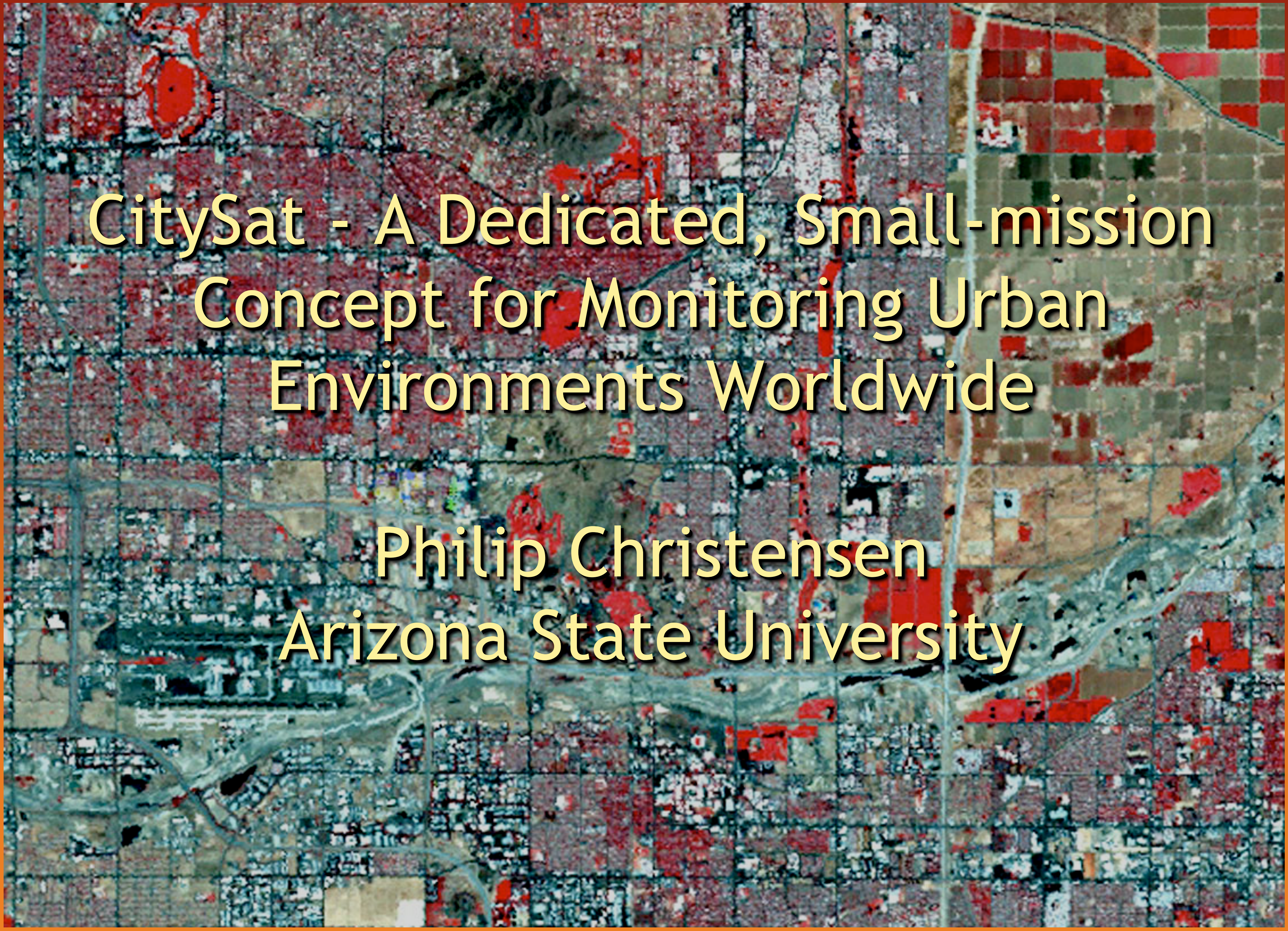
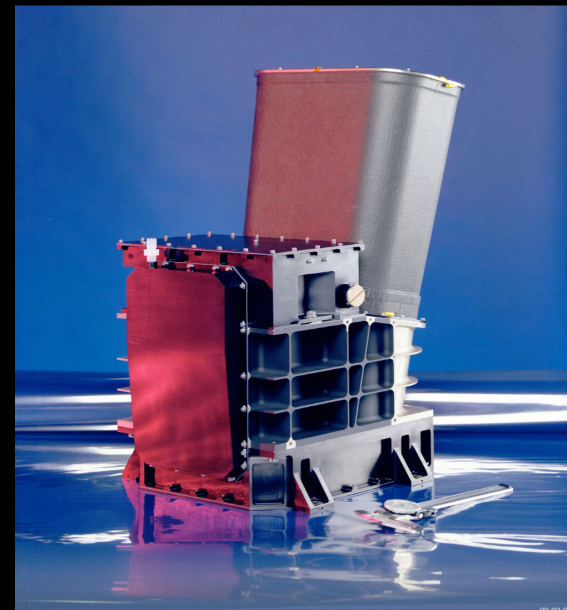


CitySat - A Dedicated, Small-mission Concept for Monitoring Urban Environments Worldwide

Philip Christensen
Arizona State University

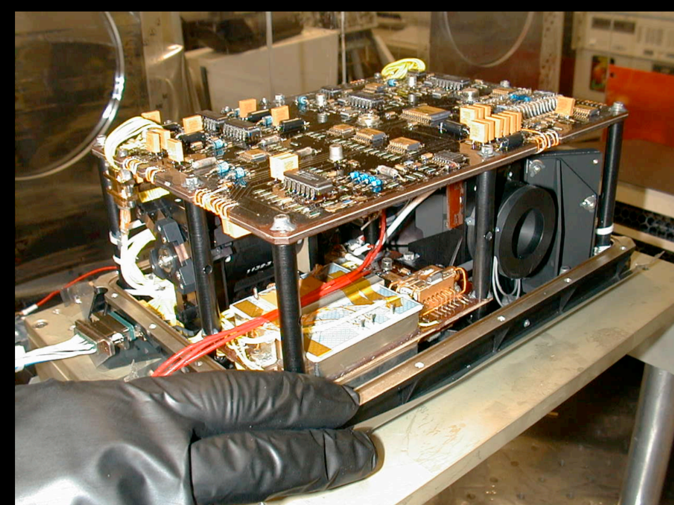
Mars Global Surveyor TES

Mars Odyssey THEMIS

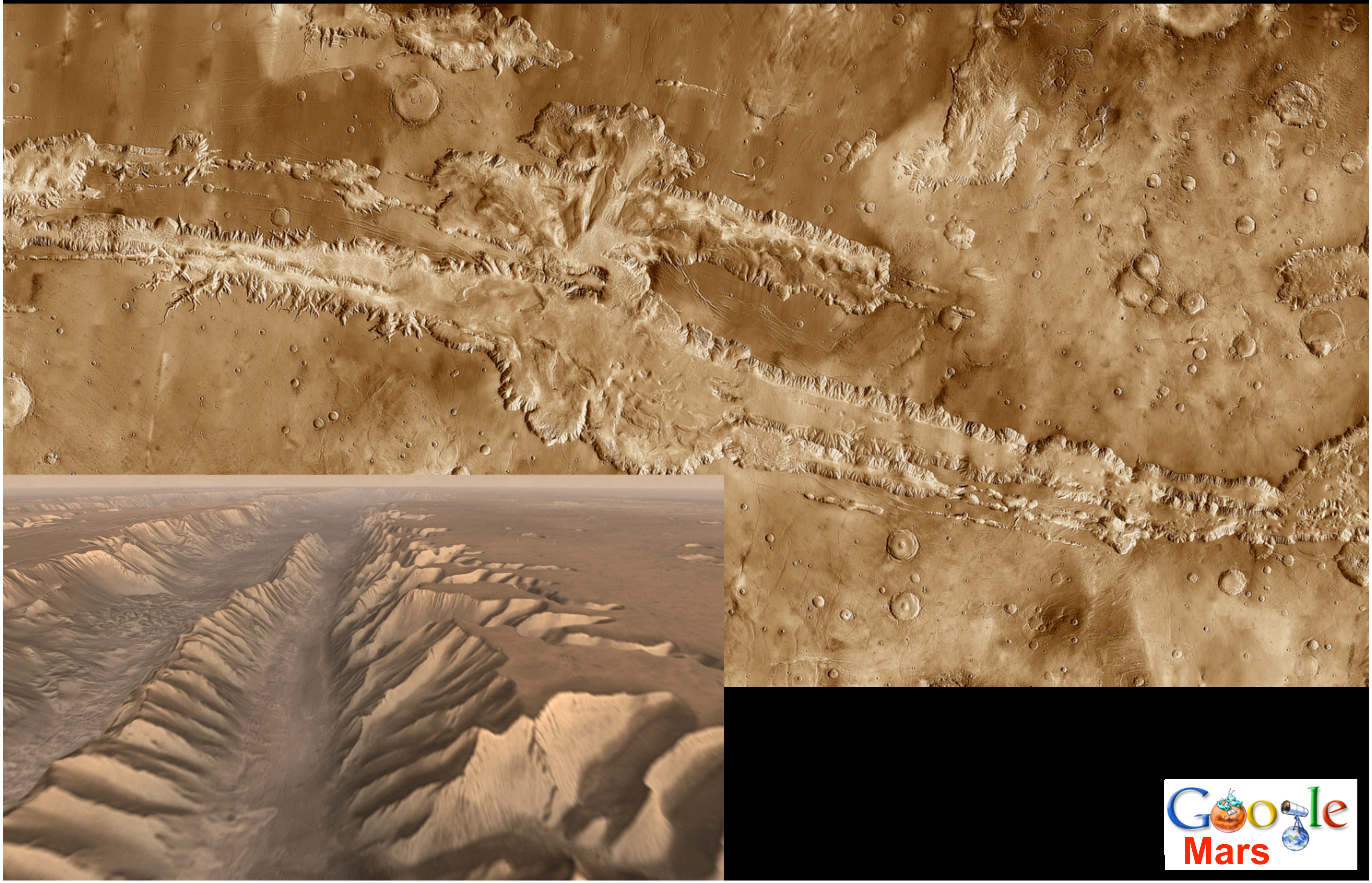


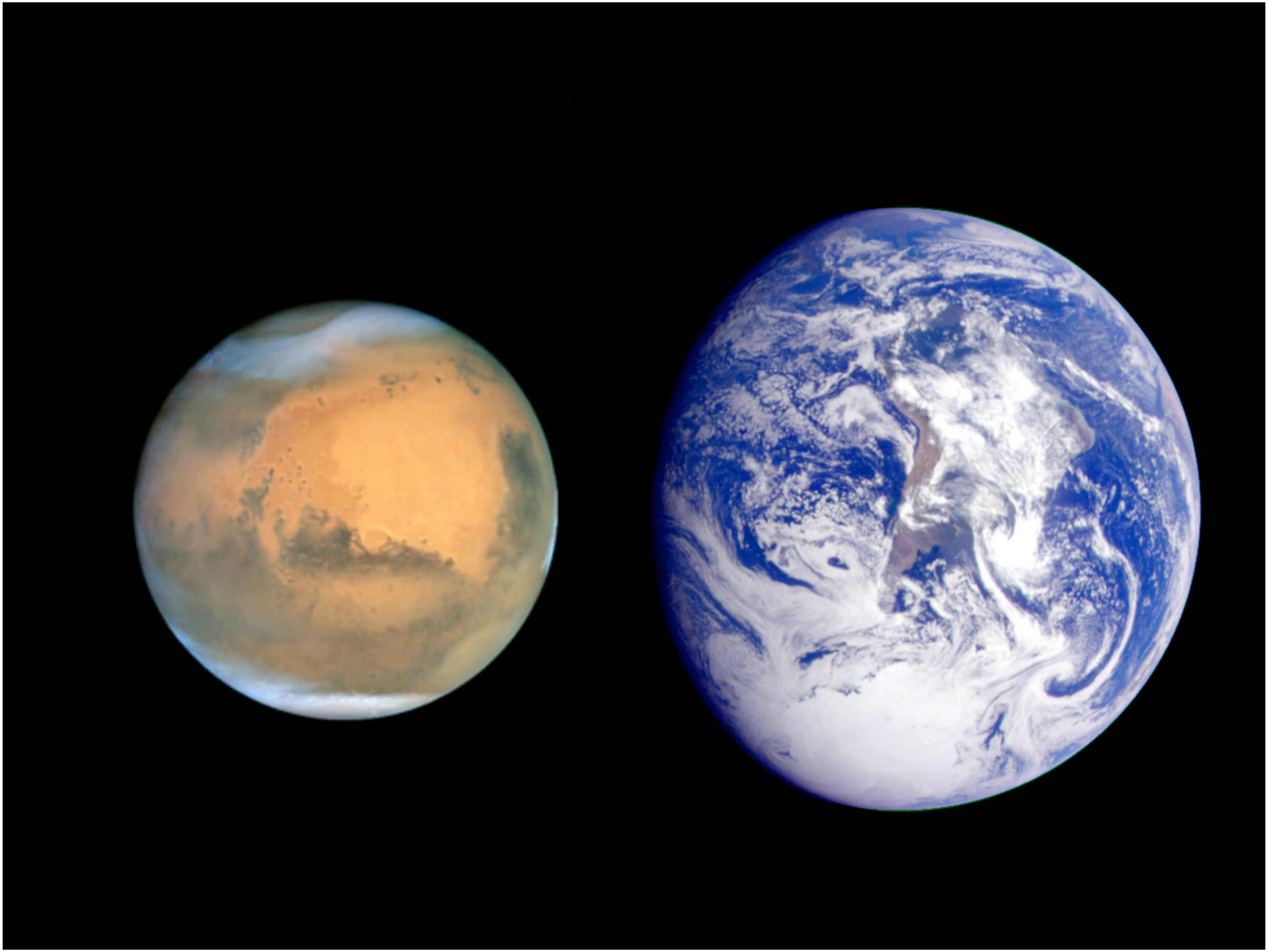
Spirit Rover Mini-TES

Opportunity Rover Mini-TES



THEMIS Infrared Mosaic of Valles Mariners



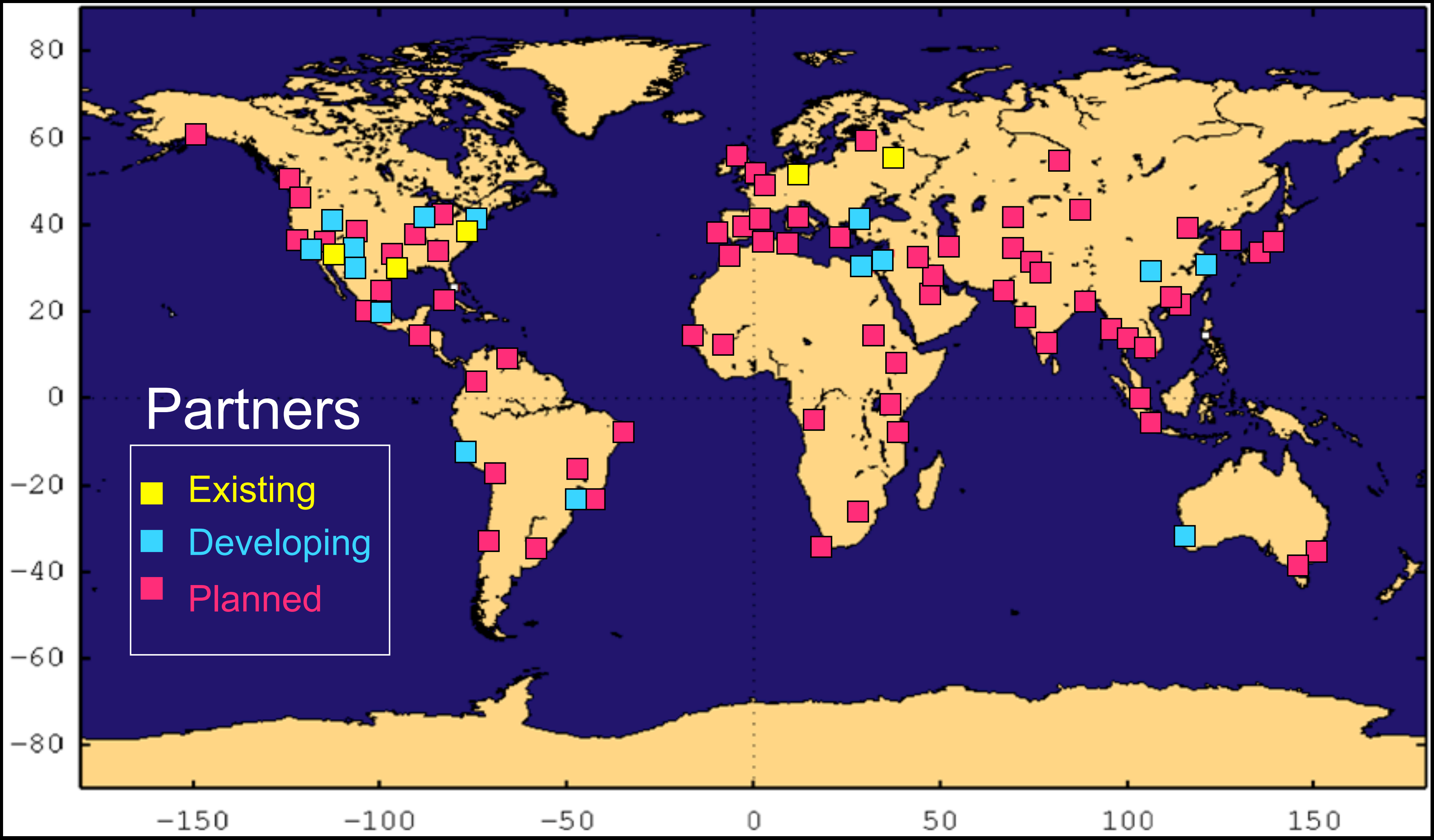


CitySat Overview

- Why?
  - Cities and urban environments are not routinely monitored nor systematically studied, yet represent an important, and rapidly growing, component of global climate system
    - 100-Cites Project begun in 1997 as member of ASTER science team
    - Despite concerted efforts, city observations often fall to low priority
    - ASU hosted a workshop on "Next Generation Urban Observations" in April 2003

100 Cities Project:

Standardized, repeated urban remote sensing



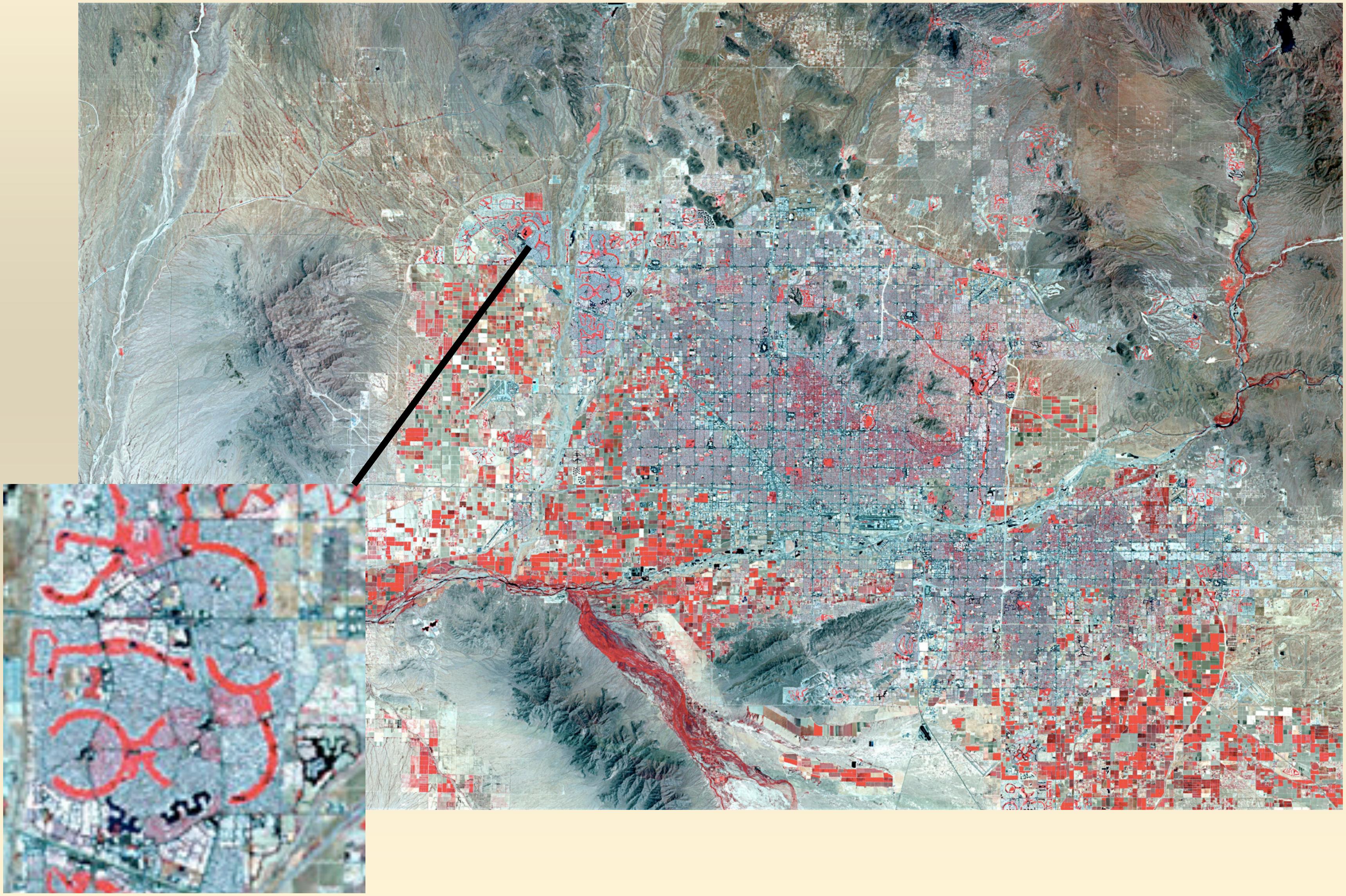
Key science questions and issues

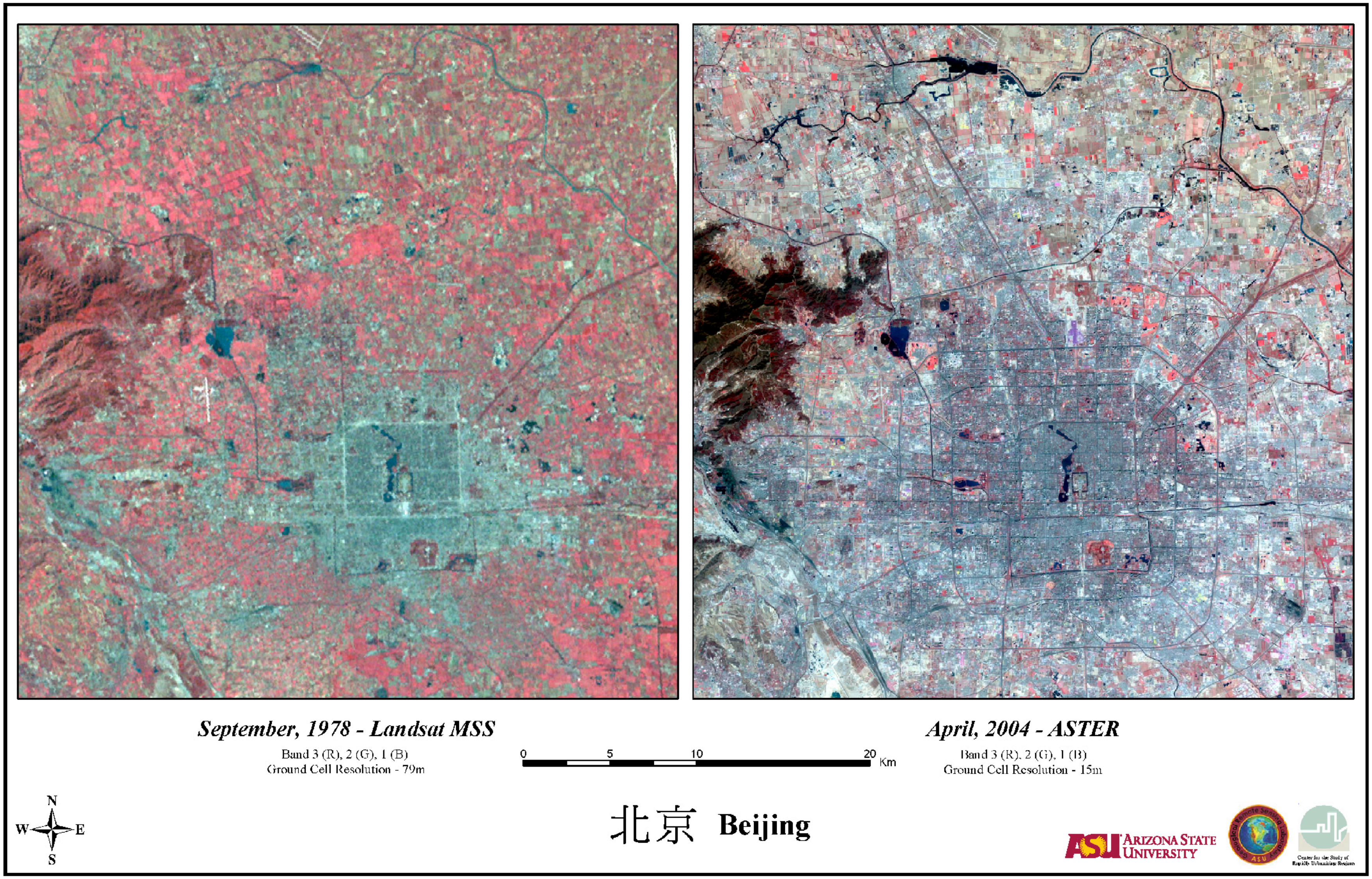
- Assess affects that cities have on local and regional meteorology, climate, air quality, and human and ecosystem health
- Understand urban growth impacts on key parameters, such as energy and water
- Quantify thermal energy fluxes across heterogeneous urban surface
- Understand and model the effect of urban land cover on land-atmosphere interactions
- Hazard assessment
- Urban-rural-agricultural-natural boundary changes and effects through time

CitySat Concept

- Small, focused mission that provides frequent (≤3 day repeat cycle) observations of cities worldwide
- Research science, not “operational”, approach
  - Complements large missions
  - Rapid respond to new discoveries and needs
  - Opportunity to try new approaches and observations
- Small instrument approach
  - What can be done with existing, low-cost instruments
  - Not, what is everything everyone might want to measure

Phoenix Regional View - 1998

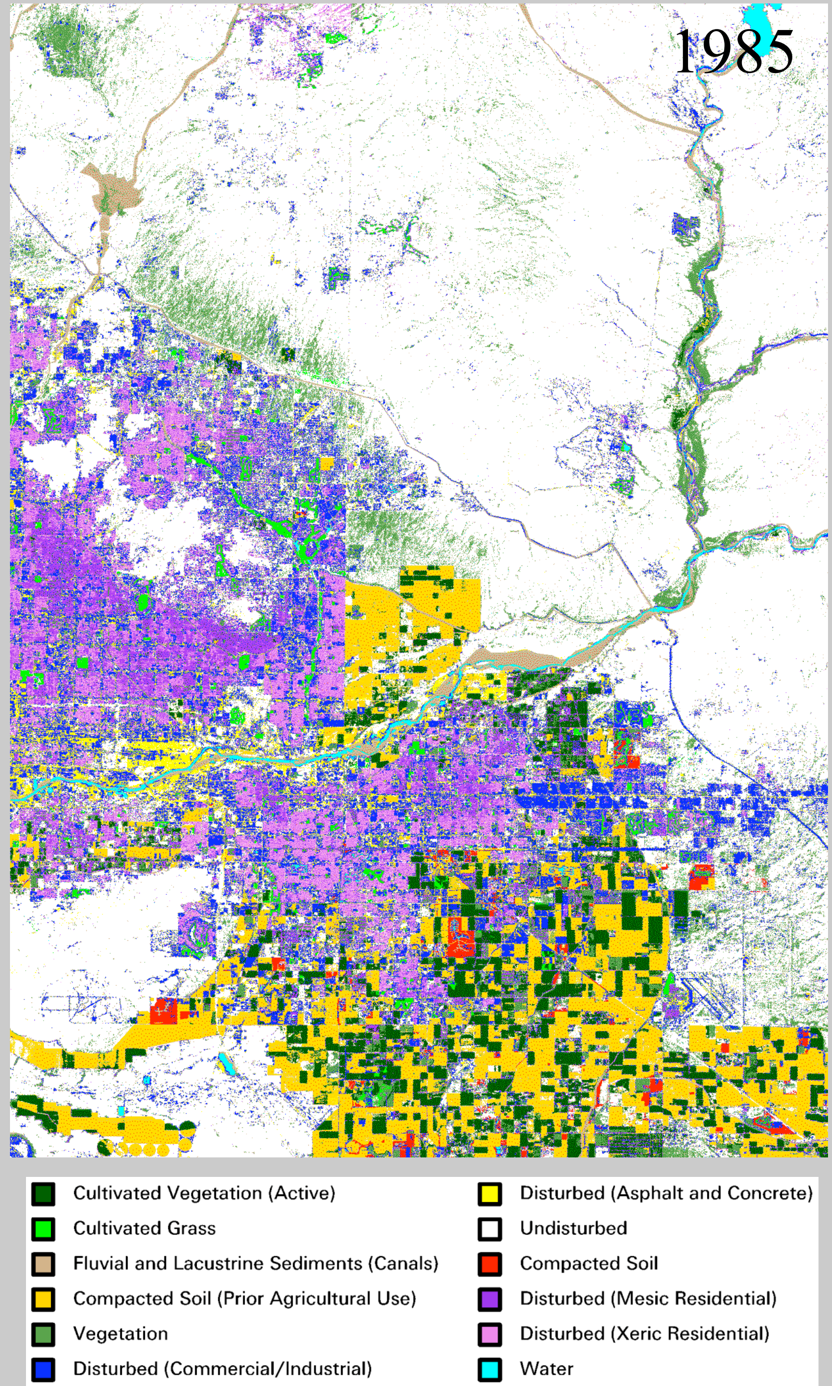



September, 1978 - Landsat MSS
Band 3 (R), 2 (G), 1 (B)
Ground Cell Resolution - 79m
0 5 10 20 Km
April, 2004 - ASTER
Band 3 (R), 2 (G), 1 (B)
Ground Cell Resolution - 15m
N
W E
S
北京 Beijing
ARIZONA STATE UNIVERSITY

Land-Cover Classification

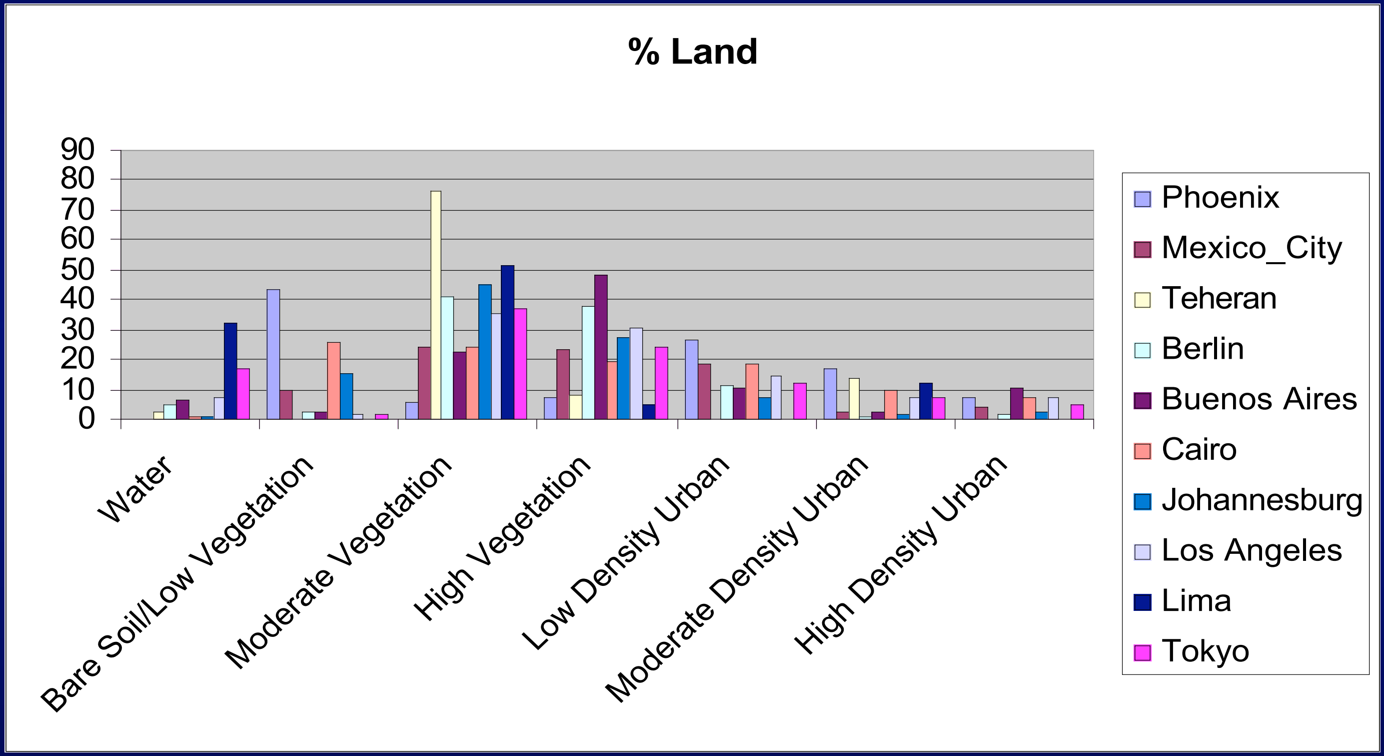
0 10 km

- Can identify various natural and built classes
- Temporal data series can be used to track changes/conversion between land-cover types/land use
- Neural networks and image segmentation techniques also powerful emerging tools



NSF Long Term Ecological Research Site Grant to ASU
(Christensen, Stefanov, Ramsey 2001-present)

ASU 100-Cities Classification Pilot Study – 10 Cities: % Land Cover/Class

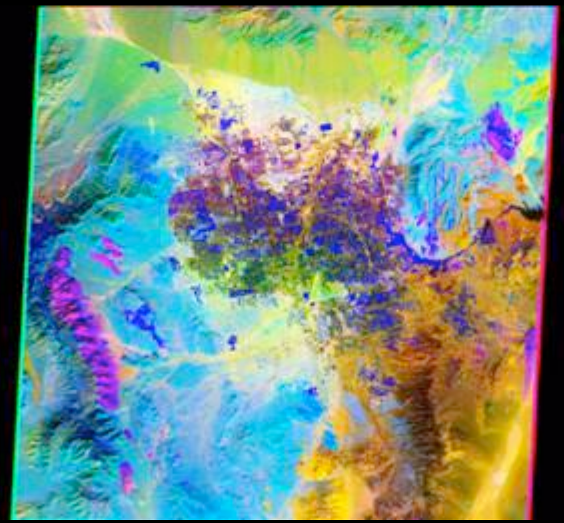


CitySat Approach (con’t)

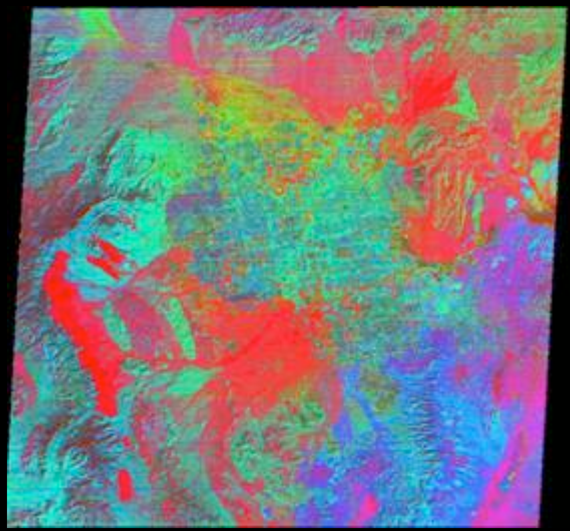
- Visible, near-IR, thermal-IR instruments
- Include an appropriate visible imager, but don’t duplicate expensive, existing capability
    - Example: Very high resolution imagery available but don’t necessarily need it every day or week

Multi-Wavelength Approach

Visible to near-infrared
15 m/pixel



Shortwave infrared
30 m/pixel



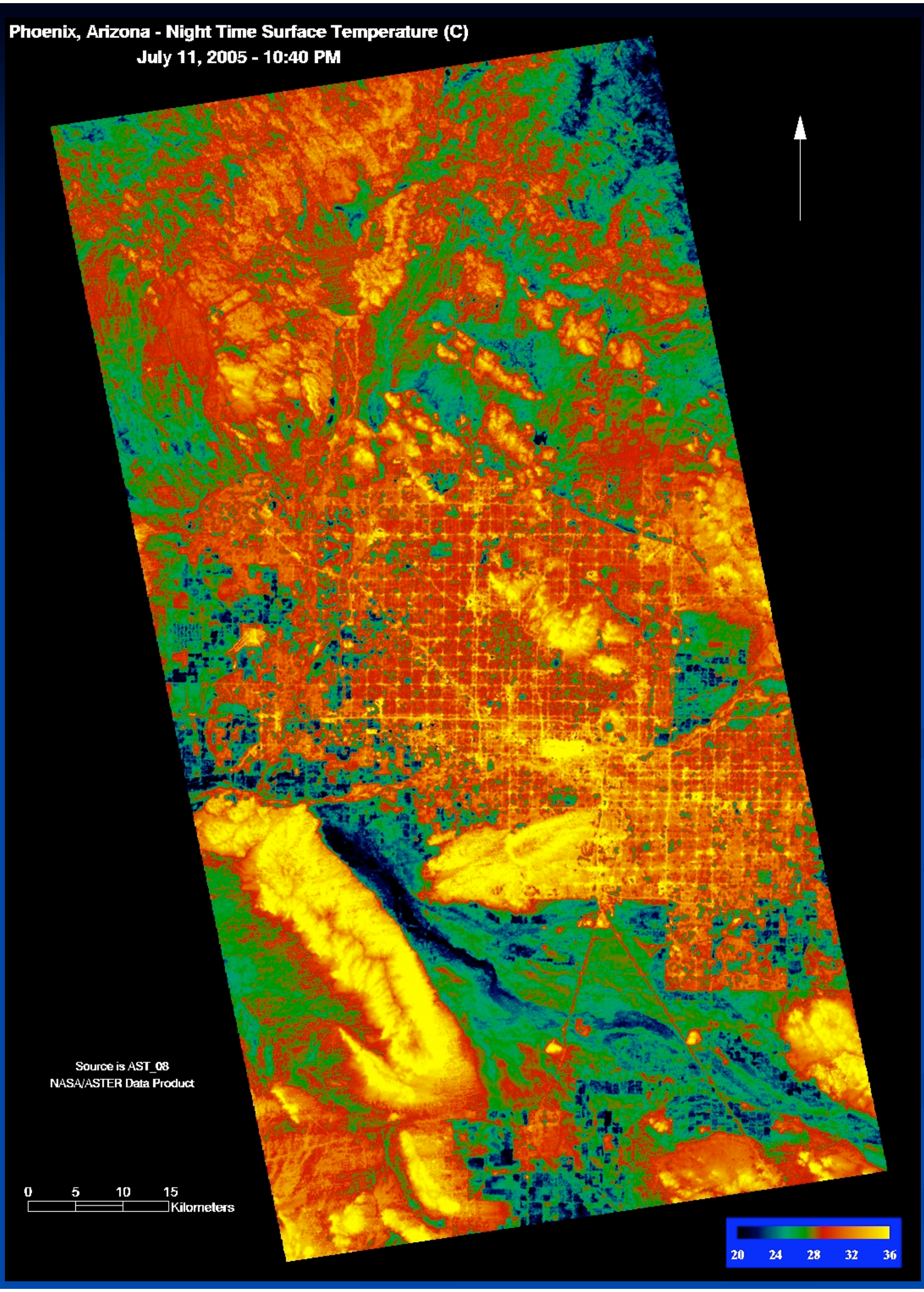
Thermal infrared
90 m/pixel

- Major land cover classes
- Vegetation health
- Soil properties
- Soil contamination

- Urban surface materials
- Rooftop materials
- Energy use
- Fugitive dust production
- Metal contamination
- Ecological communities

- Surface energy balances
- Regional climate models
- Anthropogenic heat sources
- Heat island development
- Surface composition

Las Vegas, NV, 17-Oct-2000



Urban Heat Island Maps

Phoenix – Nighttime

ASTER Surface Temperature

July 11, 2005

Max Daytime Temperature
43 °C / 111 °F

Time	Temperature
10:51 PM	98.1 °F / 36.7 °C

Urban Heat Island

Daytime Temperature

Scottsdale, AZ

CitySat Mission Design

- Obtain frequent data of all large cites worldwide
  - 2-5 times per week
  - Visible through infrared
  - Day/Night
  - Gimbaled for off-nadir pointing
    - ~±20°
    - Provides much more frequent coverage for modest field of view instrument
      - Example: ±20° would reduce repeat time from 16 days to 3 days
  - Non-nadir viewing
    - 3-D observations of urban heat island

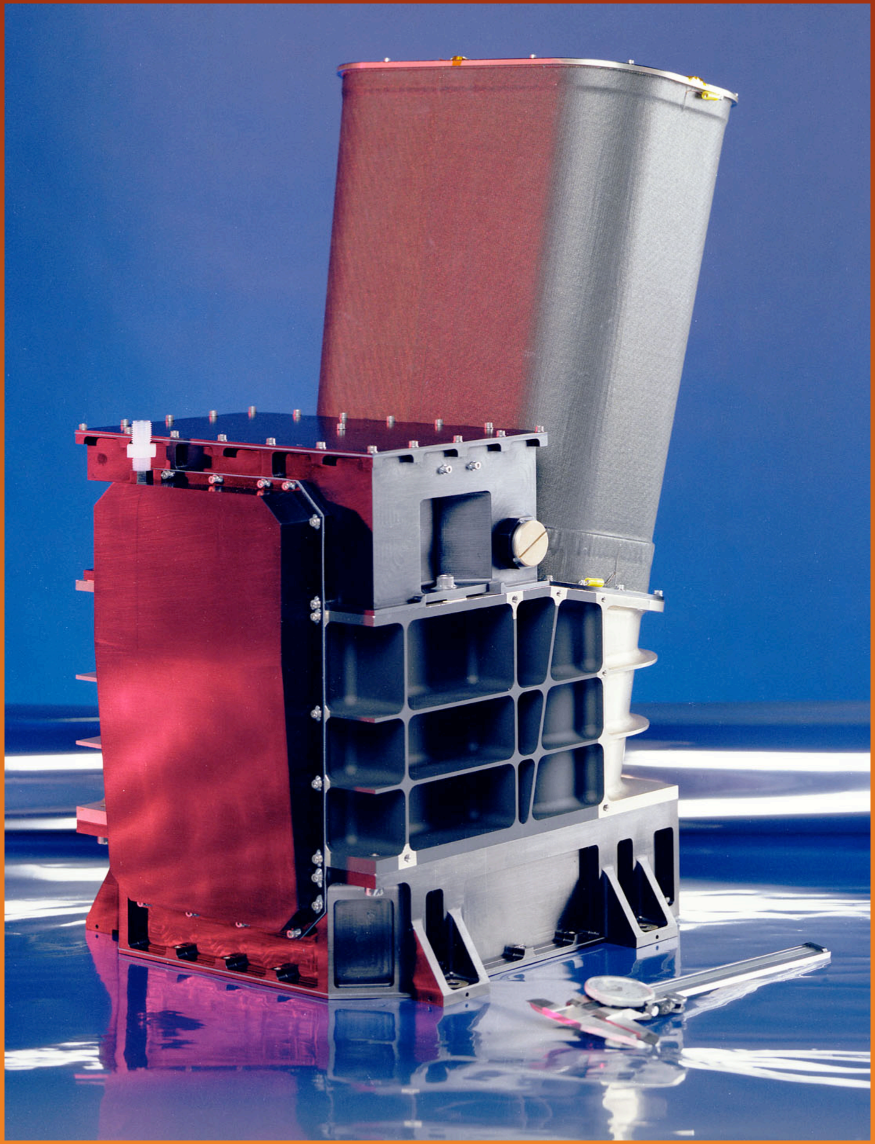
Suggested CitySat Instrumentation

- Visible
  - 5-m
  - 5 spectral bands
- Near-IR
  - 15-m
  - 5-10 spectral bands
- Thermal IR
  - 40-m
  - 5-10 spectral bands
- (Imaging Lidar)

THEMIS Instrument

- 9-band multi-spectral IR imager
  - Uncooled microbolometer
  - 6.5-15.5 μm
- 5-band visible imager
  - 0.43-0.85 μm
- 100-m spatial resolution in IR
- 18-m spatial resolution in visible

- Mass: 12.2 kg
- Size: 29 x 38 x 55 cm
- Power: 14 W



Instrument Concepts

Element	THEMIS	E-THEMIS	Aggressive	Cooled
Altitude	400 km	400 km	520 km	520 km
Ground Velocity	7.2 km/sec	7.2 km/sec	7.0 km/sec	7.0 km/sec
Effective Aperture	12 cm	14 cm	37 cm	39 cm
Array Size	320x240	640x480x2	640x480	1024x1x5
Detector Size	50 µm	25 µm	25 µm	25 µm
Operating Temp	300 K	300 K	300 K	60 K
Frame Rate	30 Hz	48 Hz	48 Hz	---
# Spectral Bands	9	8	8	5
Spot Size (w/ IMC)	110 m	55 m	30 m	20 m
Swath Width	32 km	32km/64 km	19 km/38 km	60 km
NEDT (295 K; 10µm)	0.1 K	0.2 K	0.2 K	0.02 K
Instrument Cost	$10M	$15M/$25M	$20M/$30M	~$150

CitySat Mission Conceptual Design

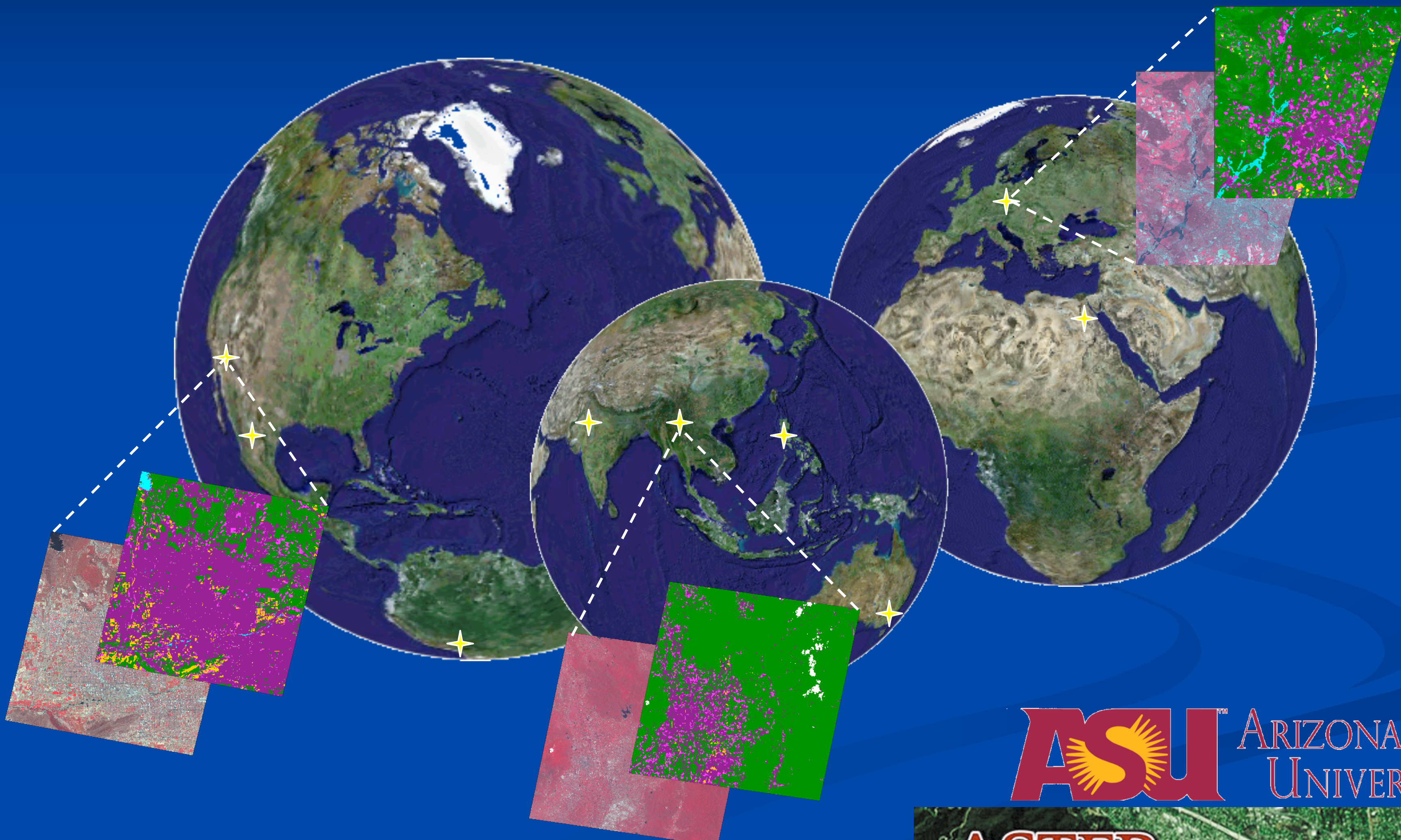
- Small spacecraft bus ($25 M)
- 2-3 modest instruments based on existing designs
  - Visible through infrared ($40 M)
- Small launch vehicle ($30 M)
- Operated from a university or similar research institution
- Extended team of science investigators
- Dedicated spacecraft
  - 52° inclination; 93 minute period
  - ~3-day repeat cycle
  - Fixed or varying solar illumination angle
  - Orbit would cover:
    - Majority of urban centers
    - Significant number of continental lakes and coastal waters, volcanic hazards, alpine glaciers

Where to go next?

- Articulate key science planning issues for urban and measurement requirements for environmental assessment and monitoring
- Address the question of whether a small mission could address critical pieces of the global environmental monitoring program
    - Next planned near-IR/thermal-IR mission is HyspIRI
        - Tier 2 mission in the 2007 NRC Decadal Survey
- Venture-class mission could be an opportunity for a dedicated urban satellite
    - ≤$100 M over ~2 years

100 CITIES PROJECT

Sensing for Solutions — Bridging Cities and Science



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ASTER

Advanced Spaceborne Thermal Emission and Reflection Radiometer

Example: ASU Mission Operations

- THEMIS daily image targeting
  - Manual and automated image targeting
  - 100-200 images per day
- Data processing
  - 300-node computing cluster
  - 0.5 Gbytes of data downlinked per day
  - Full data calibration
  - 100 Terabytes of on-line storage
- Data distribution
  - 13 Co-Investigators in U.S.
  - ~ 1-Tbyte distributed to each Co-I per month
- Current ASU Mars mission staff
  - 4 Staff Scientists
  - 2 Data Processors
  - 7 Software Engineers
  - 1 Web Administrator
  - 5 Graduate Students
  - 3 Mission Planners
  - 2 Data Validation/Archivists
  - 2 System Administrators
  - 2 Administrative Staff

IR Imager Example

Element	Earth THEMIS	Mars THEMIS
Altitude	520 km	400 km
# Spectral Bands	8	10
Ground Velocity	7.0 km/sec	3.0 km/sec
Effective Aperture	37 cm	12 cm
Array Size	640 x 480	320 x 240
Detector Size	25 µm (95% fill)	50 µm (60% fill)
Frame Rate	48 Hz	30 Hz
Time Delay Integration	40 samples	16 samples
IFOV (with IMC)	40 m x 40 m	100 x 100 (no IMC)
Swath Width	20 km	32 km
NEDT	0.2 K (@295 K)	0.1k (@295K)